

Laboratory 1: Electric Charges

Electromagnetism describes the interactions between charged objects. These interactions depend on the nature and strength of the charges. A first step in understanding electromagnetism is to classify the possible types of charge and provide methods for determining the type of charge that any object may have.

A complete classification can be attained by observing the forces exerted by various charged objects on each other. This laboratory focuses on the qualitative aspects of classifying charged objects and their interactions.

1 Electrostatic properties of pulled tape

The important qualitative features of electrostatics can be illustrated via a variety of demonstrations involving strips of scotch tape prepared in two distinct ways. It is crucial to note that, once each strip has been prepared, the relevant electrostatic properties of the tape typically persist for upwards of 10 minutes unless the tape is rubbed or lies in contact with a surface. Thus, it is vital to minimize contact between the tape and its surroundings after it has been prepared.

- a) Prepare a U-type strip of tape (see page 9) and suspend it from the underside of the desk.
- b) Place a variety of objects (e.g. a pen, a piece of paper, your hand) near to, but not touching, the strip of tape. Describe the effects of these on the tape.

The lower piece of tape is attracted
to anything you put near it.

The upper piece of tape is repelled
from anything you put near it.

If there are **no effects** on the tape, then this indicates that the **preparation or storage of the tape was defective**. This is one way of verifying that the tape is correctly prepared.

- c) Attach a small piece of paper to a thread. Suspend the paper near to, but not touching, the tape. Describe what happens to the tape and the paper. The effect is weak but noticeable. If the paper touches the tape the effect may be reversed (if this happens rub the paper with your finger and repeat the process). Ignore gravity and the contact forces exerted by the objects that support the tape and paper.

The paper attracts to both pieces

During the preparation process the tape has clearly acquired a property which enables it to exert attractive forces on surrounding objects. This tape is **electrically charged**.

2 Electrostatic properties of two pieces of U-type tape

The nature of the electric charge acquired by a piece of tape can be explored by bringing two pieces of tape into close proximity.

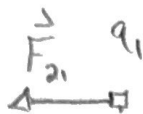
- a) Prepare two U-type pieces of tape. **Without using any observations** which of the following could you conclude is true?
- i) The tapes are oppositely charged.
 - ☒ ii) The tapes are either both charged with the same type of charge or they are both neutral.

Explain your answer.

- b) Bring the two U-type pieces of tape near to each other. Which of the following do you observe?
- i) The tapes attract.
 - ☒ ii) The tapes repel.
 - iii) There is no interaction between the tapes.
- c) Move one of the pieces of U-type tape around the other. Does the interaction between the two depend on their relative orientations?

No orientation does not matter

- d) Sketch a diagram indicating the forces exerted on each of the two pieces of tape. Ignore gravity and the contact forces exerted by the objects that support the tapes.



3 Electrostatic properties of two pieces of L-type tape

- a) Prepare two L-type pieces of tape. **Without using any observations** which of the following could you conclude is true?
- i) The tapes are oppositely charged.
 - ☒ ii) The tapes are either both charged with the same type of charge or they are both neutral.

Explain your answer.

They should have the same charge because they are from two similar systems.

- b) Bring the two L-type pieces of tape near to each other. Which of the following do you observe?
- ☒ i) The tapes attract.
 - ii) The tapes repel.
 - iii) There is no interaction between the tapes.

4 Electrostatic properties of an L-type tape and a U-type tape

- a) Prepare an L-type tape near a U-type tape. **Without using any observations** which of the following could you conclude is true?
- ☒ i) The tapes are oppositely charged or they are both neutral.
 - ii) The tapes are both charged with the same type of charge.

Explain your answer.

They are prepared in separate systems so opposite charges.

- b) Bring an L-type tape near a U-type tape. Which of the following do you observe?
- The tapes attract.
 - The tapes repel.
 - There is no interaction between the tapes.
- c) Sketch a diagram indicating the forces exerted on each of the two pieces of tape. Ignore gravity and the contact forces exerted by the objects that support the tapes.



5 General interactions between tape types

The observations of the interactions between all possible combinations of types of tape can be condensed into a single rule regarding electrostatic interactions.

- a) Based on your observations, how would you describe the interaction between two types of tape which have the same type of charge? Explain your answer.

They will repel because like charges repel

- b) Based on your observations, how would you describe the interaction between two types of tape which have the opposite types of charge? Explain your answer.

They will attract because opposite charges attract

6 Exact nature of charge on the tapes

The nature of the charges on the U and L-types of tape can be determined by bringing an object, whose type of charge is known into proximity with the tapes.

- a) Suspend a U and an L-type piece of tape from the underside of the desk. Rub a plastic object (but *not* a pen containing ink) on fabric and bring it near to the

each of the pieces of tape. Based on your observations, which type of tape has the same charge as the plastic?

upper piece

- b) It is known that the rubbed plastic is negatively charged. Based on this, describe the charges on the two types of tape.

Type	Charge
U	—
L	+

7 Determining the charge on any object via the two types of tape

The two types of tape can be used to determine the charge on any object. However, as this exercise will illustrate, you have to be careful when doing this!

- a) Suppose you are given an object that is either positively or negatively charged. In addition you are given a piece of U-type tape and a piece of L-type tape. Describe explicitly *in point form* a procedure that you could use to determine which type of charge the object has.

- Bring the L-type close without touching
- Record the response
- Bring the U-type close without touching
- Record the response
- If the L-type is attracted, the object is negatively charged
- If the U-type is attracted, the object is positively charged

- b) Construct a "paper (or foil) pendulum" by suspending a small piece of paper from a thread. Repeat this so that you have two paper pendulums. Bring one near to the U-type tape and observe the force exerted by the tape on the pendulum. Consider only the observations before the pendulum touches the tape. Based on your observation, what type of charge does the paper pendulum appear to have?

either negative or neutral

Rub the paper pendulum with your finger. Now bring it near to the L-type tape. Based on your observation, what type of charge does the paper pendulum appear to have? Does this agree with the conclusion from your observation when using U-type tape?

The - L-type would be (+), the - paper would be positive or neutral.

- c) Bring the two paper pendulums near to each other. Do they attract or repel each other? Based on these observations would you say that the paper is charged?

They don't do anything because the paper is neutral.

or neutral?

1. The first part of the paper is devoted to a discussion of the various methods of determining the pH of a solution.

2. The second part of the paper is devoted to a discussion of the various methods of determining the concentration of a solution.

3. The third part of the paper is devoted to a discussion of the various methods of determining the molar mass of a substance.

You should have observed that charged objects will frequently exert a force on neutral objects (this will be explained later). However, it is still possible to determine whether an object is charged using U and L-types of tape.

- d) There is a common feature to the force exerted by either a U or an L type tape on a neutral object. Identify this and describe what sort of force is never exerted by either a U or an L type tape on a neutral object. Based on this, describe explicitly a method, using U and L-type tapes that will definitely determine whether an object is charged and what its charge is.

A u or an L type tape will never repel a neutral object.

- Bring a u-type tape to an object and record what happens.
- Repeat with an L-type tape.
- If the tape repels, then the object is charged
- If the tape attracts, the object could be neutral
- If the L-type repels, the object is positive.
- If the u-type repels, the object is negative.

8 Preparing the Tape

There are two types of tape that need to be produced. The methods of producing both types of tape utilize a **base layer** of tape. In order to make the **base layer** proceed as follows.

- a) Stick an entire 20 cm long strip of tape to the surface of the desk. Gently rub the tape several times with your finger. The effects that this accomplishes are accentuated by first breathing on your hand (this is not magic - there is a good reason for this).

In order to make an "upper" or **U-type** piece of tape proceed as follows:

- a) Gently rub the base layer with your finger several times.
- b) Remove a 20 cm strip of tape off the roll and bend one end over to form a handle. Stick this tape down on top of the base layer and gently rub it with your finger several times. Label it "U."
- c) Quickly pull the U tape off the base layer. Minimize contact between the tape and any surrounding objects. Store the tape by suspending it from one end from the underside to the desk for later use.

In order to make a "lower" or **L-type** piece of tape proceed as follows:

- a) Gently rub the base layer with your finger several times.
- b) Pull a 20 cm strip of tape off the roll and bend one end over to form a handle. Stick this tape down on top of the base tape and gently rub it with your finger several times. This will form an "lower" type tape. Label it "L."
- c) Pull a third 20 cm strip of tape off the roll and bend one end over to form a handle. Stick this tape down on top of the L tape and gently rub it with your finger several times. This will form an "upper" type tape. Label it "U."
- d) Slowly pull the L tape up (the U tape will be lifted along with it). Without separating the U and L tapes, hang them from the desk and gently rub both with your fingers.
- e) Rapidly separate the U and L tapes. Minimize contact between the tape and any surrounding objects. Each can be suspended by one end from the underside to the desk for later use.